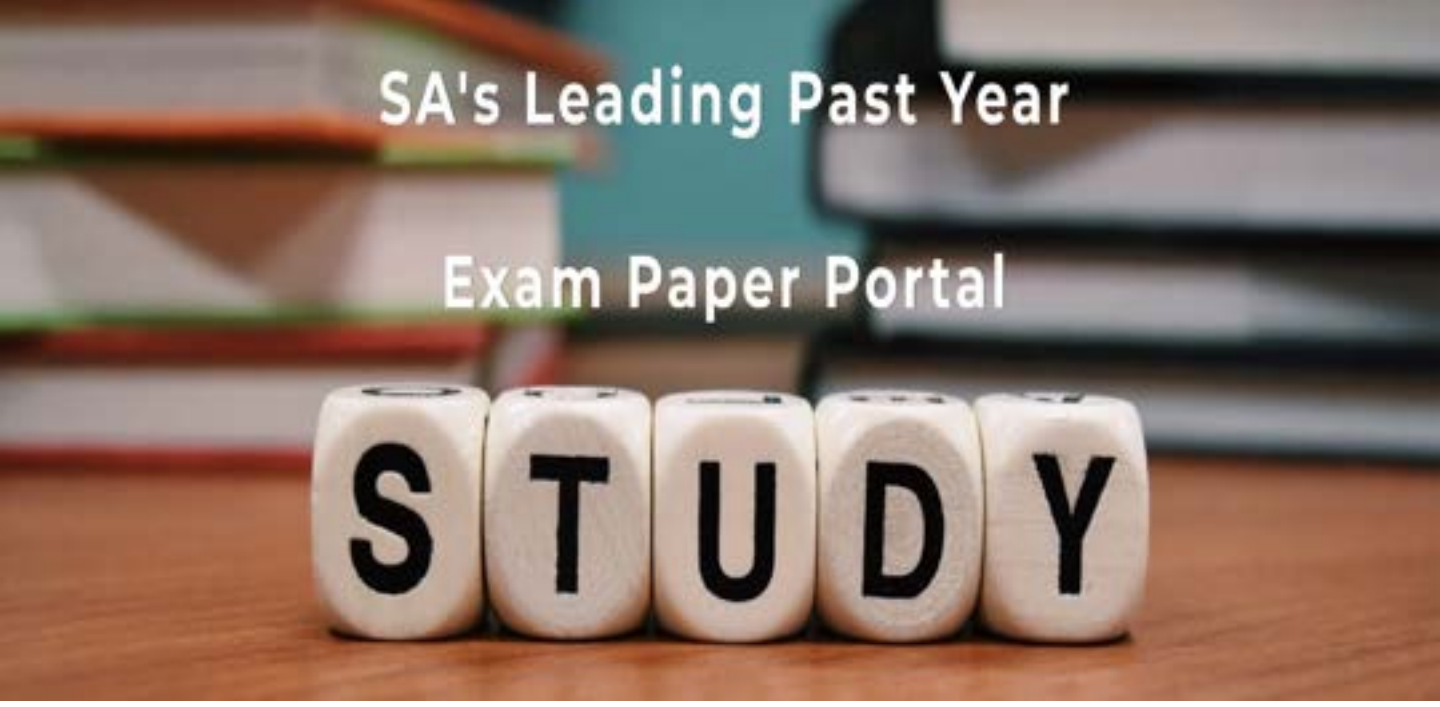

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1. INTRODUCTION

The declaration of COVID-19 as a global pandemic by the World Health Organisation led to the disruption of effective teaching and learning in many schools in South Africa. The majority of learners in various grades spent less time in class due to the phased-in approach and rotational/ alternate attendance system that was implemented by various provinces. Consequently, the majority of schools were not able to complete all the relevant content designed for specific grades in accordance with the Curriculum and Assessment Policy Statements in most subjects.

As part of mitigating against the impact of COVID-19 on the current Grade 12, the Department of Basic Education (DBE) worked in collaboration with subject specialists from various Provincial Education Departments (PEDs) developed this Self-Study Guide. The Study Guide covers those topics, skills and concepts that are located in Grade 12, that are critical to lay the foundation for Grade 12. The main aim is to close the pre-existing content gaps in order to strengthen the mastery of subject knowledge in Grade 12. More importantly, the Study Guide will engender the attitudes in the learners to learning independently while mastering the core cross-cutting concepts.

2. How to use this Self Study Guide?

The purpose of this study guide is to help you through the topic of chemical equilibrium.

It should be used in conjunction with the CAPS document as well as the Examination guidelines.

All definitions should be taken from Examination guidelines.

Avoid omitting key words from the definitions.

Make sure that you know the types of reactions like endothermic and exothermic reaction.

Work through the worked examples first so that you are more comfortable with questions and answers.

Work through the exercises given on your own before looking at the answers. When you are done compare your answer to the memorandum.

Make sure you first know how to explain the factors affecting chemical equilibrium position using Le Chatelier's principle.

Use the mnemonic CPT (Cape Town) to remember the factors that affect the position of equilibrium. (CPT – Concentration, Pressure and Temperature)

Make sure that when writing the Kc expression, **you show the concentration(s) of the products on the numerator and concentration of the reactants on the denominator**.

Remember the concentration in the Kc expression is raised to the power of the coefficient.

Always represent concentration using square brackets.

3. Extract from Examination Guidelines

(This section must be read in conjunction with the CAPS, p. 125–126.)

Chemical equilibrium and factors affecting equilibrium

• Explain what is meant by:

Open and closed systems: An open system continuously interacts with its environment, while a closed system is isolated from its surroundings.

A reversible reaction: A reaction is reversible when products can be converted back to reactants.

Chemical equilibrium: It is a dynamic equilibrium when the rate of the forward reaction equals the rate of the reverse reaction.

• List the factors that influence the position of an equilibrium, i.e. pressure (gases only), concentration and temperature.

EQUILIBRIUM CONSTANT (Kc)

• List the factors that influence the value of the equilibrium constant, Kc.

• Write down an expression for the equilibrium constant having been given the equation for the reaction.

• Perform calculations based on Kc values.

• Explain the significance of high and low values of the equilibrium constant

APPLICATION OF EQUILIBRIUM PRINCIPLES

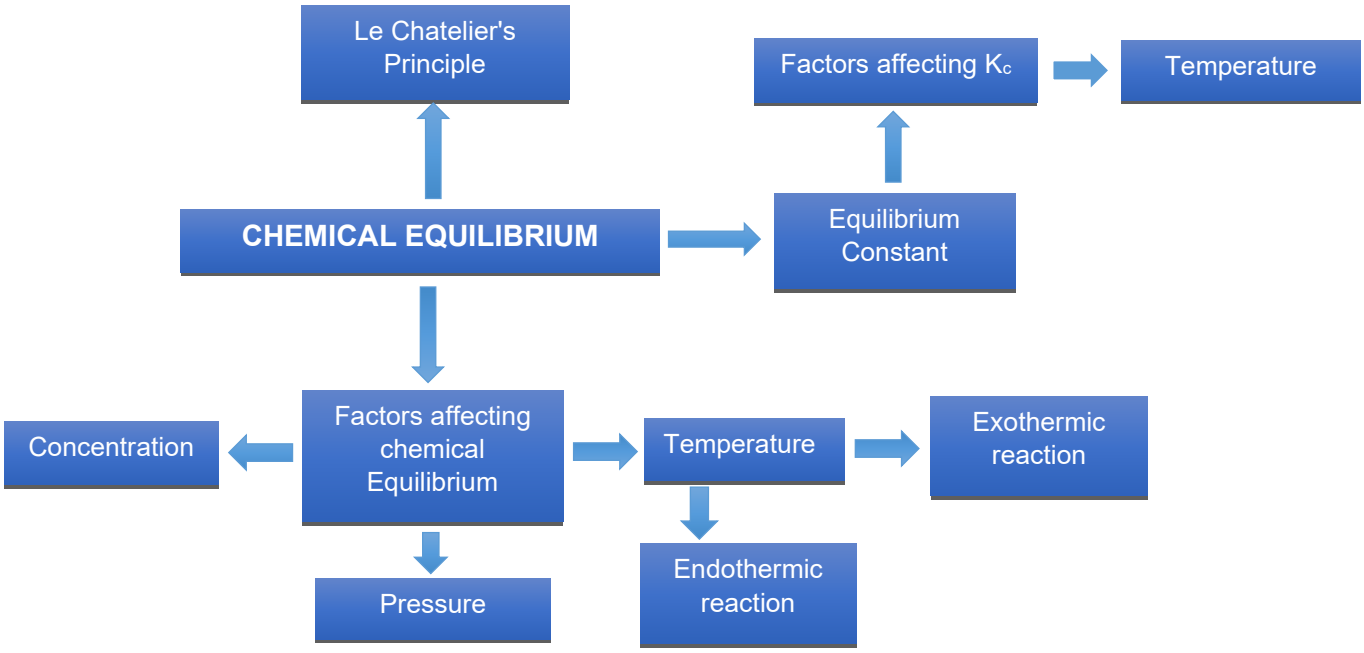
• State Le Chatelier's principle: When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.

• Use Le Chatelier's principle to explain changes in equilibria qualitatively.

• Interpret graphs of equilibrium, e.g. concentration/rate/number of moles/mass/ volume versus time graphs.

• Explain the use of rate and equilibrium principles in the Haber process and the Contact process.

4. CONTENT



4.1 Types of system

An **open system** continuously interacts with its environment.

For example, when you boil water using a container without a lid, water vapour will escape from the container to the surrounding environment.

Open system: Exchange of **energy** and **matter**.

Note that in the above system, water vapour is escaping from the container because it is open, so it means **condensation cannot take place which is the reverse reaction**.

$H_2O() \longrightarrow H_2O(g)$

A closed system is isolated from its surroundings.

. **Closed** system: Exchange of **energy** but **not matter**

In the above system, reactants and products do not escape from the system because the system is closed. No interaction with its environment. The **reverse reaction will take place in the system.**

A reaction is reversible when products can be converted back to reactants and vice versa.

Hint: Do not omit underlined key words.

Note:

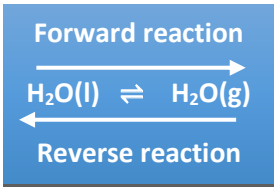
A reversible reaction consists of a forward reaction and a reverse reaction.

Reversible reaction reaches equilibrium in a closed system

Initially the rate of the forward reaction decreases since the reactants are being used.

Initially the rate of the reverse reaction increases since products are being formed.

Reversible reaction is denoted by double arrows.



4.2 CHEMICAL EQUILIBRIUM

Chemical equilibrium is a dynamic equilibrium when **the rate of the forward reaction equals the rate of the reverse reaction**

Figure 1

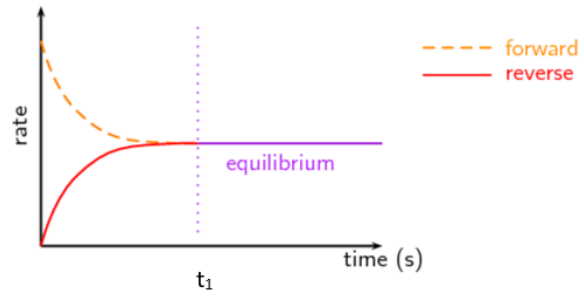
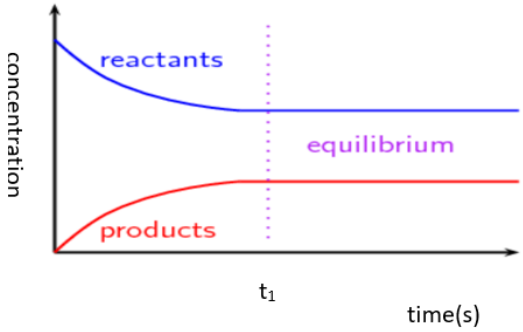


Figure 2



Note:

In both figures 1 and 2, after t_1, the reaction has reached a state of dynamic chemical equilibrium.

a chemical reaction has reached chemical equilibrium at t_1. (Where the curves flatten out or become horizontal)

After t_1 the **rate of the forward reaction is equal to the rate of reverse reaction**.

After t_1 the **concentration of products and reactants remains constant**.

AVOID saying the following:

Forward reaction is equal to the reverse reaction.

Concentration of the forward reaction is **equal** to the concentration of the reverse reaction.

Change in concentration of reactants and products are the **same.**

4.3.1 FACTORS THAT INFLUENCE THE POSITION OF A CHEMICAL EQUILIBRIUM

There are three factors that influence the position of an equilibrium

Temperature

Concentration (Only applies to **aqueous(aq)** solutions and **gases (g)**

Note**: Concentrations of pure liquids and solids remains constant** through the reaction that is why they **do not affect the chemical equilibrium**.

Pressure (gases)

Note that pressure is inversely proportional to volume.

Le Chatelier's principle

When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.

You should know the following definitions from grade 11

Exothermic reactions are reactions that **release energy**. $\Delta H < 0$ or $\Delta H = -$ kJmol^{-1}

($H_{reactants} > H_{products}$)

Endothermic reactions are reactions that **absorb energy**. $\Delta H > 0$ or $\Delta H = +$ kJmol^{-1}

($H_{reactants} < H_{products}$)

When applying Le Chatelier's Principle by changing equilibrium conditions, the equilibrium position will shift in such a way as to counteract (oppose) the disturbance.

1. TEMPERATURE

An Increase in Temperature

- Favours the endothermic reaction.

  Hint: A reaction that decreases the temperature of the system.

A Decrease in Temperature

- Favours the exothermic reaction.

  Hint: A reaction that increases the temperature of the system.

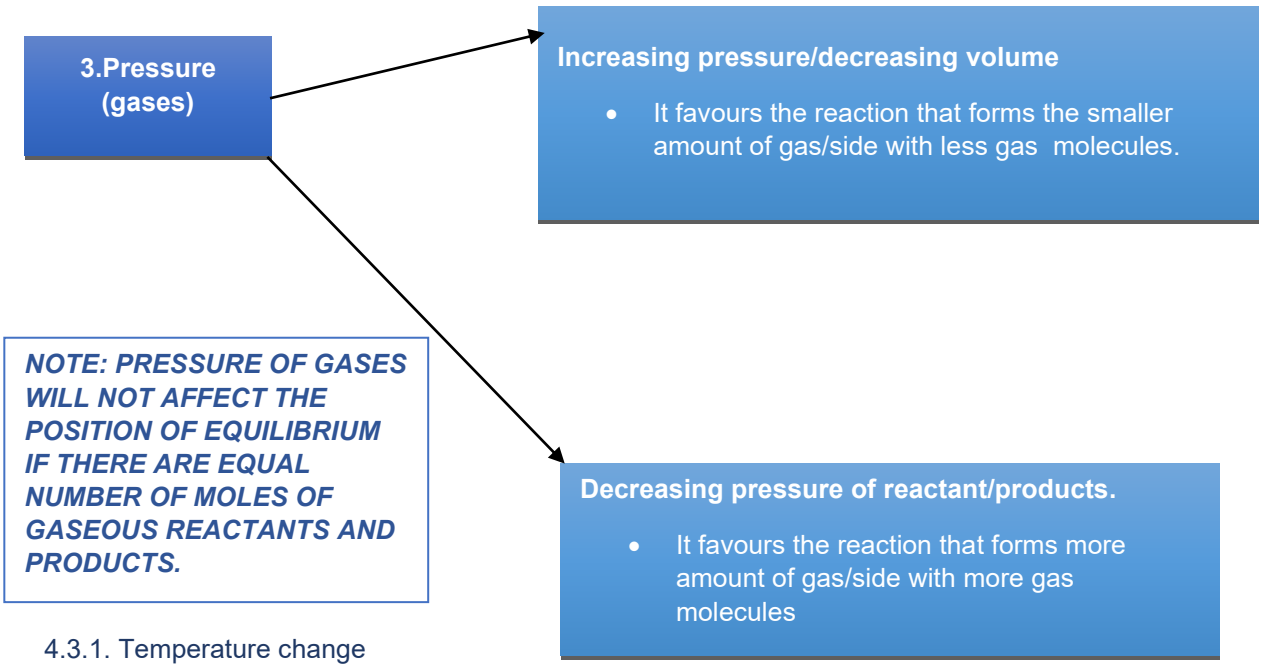
2. CONCENTRATION (AQUEOUS (aq)) AND GASES (g))

Increasing the concentration of reactants/products

- Favours the reaction that uses the substance.
  - ❖ Adding a reactant: Favours the forward reaction
  - ❖ Adding a product: Favours the reverse reaction.

Decreasing the concentration of reactants/products

- Favours the reaction that increases the concentration of a substance.
  - ❖ Removing a reactant: reverse reaction will be favored.
  - ❖ Removing a product: forward reaction will be favored.



4.3.1. Temperature change

Steps to be followed in case of change in temperature

Determine whether the forward reaction is endothermic or exothermic reaction.

NOTE IF:

$A + B \rightleftharpoons C+D \quad \Delta H > 0$ or $\Delta H = +$ kJmol^{-1}

$A + B +$ heat $\rightleftharpoons C+ D$

In the above reactions, the **forward reactions are endothermic.**

$A + B \rightleftharpoons C+D \quad \Delta H < 0$ or $\Delta H = -$ kJmol^{-1}

$A + B \rightleftharpoons C+ D +$ heat

In the above reactions, the **forward reactions are exothermic.**

Determine if the forward or reverse reaction is favoured using Le Chatelier's Principle when temperature is increased or decreased.

State how the concentration of reactants or products change.

State how will the reaction rate be affected.

Worked Example 1

Hydrogen and iodine are sealed in a 2 dm^3 container. The reaction is allowed to reach equilibrium at 700 K according to the following balanced equation:

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \Delta H > 0$

1.1 Define reversible reaction. (2)

1.2 Is forward reaction endothermic or exothermic? (1)

1.3 The temperature of the system is now increased.

1.3.1 Explain the effect of the increase in temperature on the equilibrium position using Le Chatelier's principle. (4)

1.4 The temperature of the system is now decreased.

1.4.1 Explain the effect of the decrease in temperature on the equilibrium position using Le Chatelier's principle. (3)

Solutions for Example 1

1.1 Hint: Do not omit key words

Ans: A reversible reaction is when products can be converted back to reactants. ✓✓ (2)

1.2 Hint: $\Delta H > 0$

Ans: Endothermic✓ (1)

1.3.1 Hint: Follow steps given in section (C) (4)

Increase in temperature favours endothermic reaction. ✓

Forward reaction is endothermic. ✓

Forward reaction is favoured. ✓

The rate of reactions increase.

The concentration of the HI(g) increases.✓

1.4.1 Hint: Follow steps given in section (C)

Decrease in temperature favours exothermic reaction. ✓

Reverse reaction is exothermic. ✓

Reverse reaction is favoured. ✓

The rate of reactions decrease.

The concentration of the HI(g) decreases while concentration of H_2 and I_2 increases.✓

Worked Example 2

Hydrogen gas, $H_2(g)$, reacts with sulphur powder, S(s), according to the following balanced equation:

$H_2(g) + S(s) \rightleftharpoons H_2S(g) \quad \Delta H < 0$

2.1 Define the term chemical equilibrium. (2)

2.2 Use Le Chatelier's principle to explain how will an increase in temperature affect the number of moles of H_2S at equilibrium. (4)

Solutions for worked example 2

2.1 Do not omit key words "Rate of forward reaction = Rate of reverse reaction (2)

NB: Avoid saying Forward reaction = Reverse reaction

Ans: Chemical equilibrium is a dynamic equilibrium when the rate of the forward reaction equals the rate of the reverse reaction✓✓

2.2

An increase in temperature favours the endothermic reaction. ✓ (4)

The forward reaction is exothermic. ✓

The reverse reaction is favoured. ✓

Therefore, the number of moles of H_2S decreases. ✓

4.3.2 Change in Pressure

Steps to be followed in case of change in Pressure

Balance the chemical equation

Count the number of gas moles on both sides of the reaction using balanced equation coefficients of reactants and products.

Determine which reaction has more or less number of gas moles between forward reaction and reverse reaction

$2A(g) + B(g) \rightleftharpoons C(g)+D(g)$

3 moles 2 moles

Forward reaction has 2 moles of gas molecules

Reverse reaction has 3 moles of gas molecules

Determine if the forward or reverse reaction is favoured using Le Chatelier's Principle when pressure is increased or decreased.

State how the concentration of reactants or products change.

Worked Example 3

Hydrogen gas, $H_2(g)$, reacts with sulphur powder, S(s), according to the following balanced equation:

$H_2(g) + S(s) \rightleftharpoons H_2S(g) \quad \Delta H < 0$

3.1	State Le Chatelier's principle	(2)
3.2	Is the reaction reversible? Explain the answer.	(3)
3.3	Which reaction has more number gaseous moles?	(1)
3.4	Which reaction has least number gaseous moles?	(1)
3.5	How will the increase in pressure affect the amount of $H_2S(g)$?	(1)

Solutions for Worked Example 3

3.1 When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance.✓

3.2 Avoid saying (2)

There is a double arrow.

Reactants can be converted to products

Ans: Yes. ✓ Products can be converted back to reactants. ✓

3.3 Reverse reaction

3.4 Forward reaction

3.5 Hint: Number of moles on both sides are equal. (1)

Increase in pressure will not affect the chemical equilibrium but the rate of forward reaction and rate of reverse reaction increase equally.

Ans: No effect

4.3.3 Change in concentration

Worked Example 4

The following reaction reaches chemical equilibrium in a sealed container at 70 ºC.

N_2O_4 (g) ⇌ 2 NO_2 (g)

4.1 What is the effect of adding more N_2O_4 on the number of moles of NO_2 at equilibrium? (3)
Explain using Le Chatelier's principle.

Solution

4.1 Increasing the concentration of N_2O_4 (g) will favour the reaction that decreases the concentration of N_2O_4 (g). ✓

Forward reaction is favoured. ✓

The concentration of NO_2 (g) increases.

OR More number of moles of NO_2 (g) will be formed. ✓

4.4 EQUILIBRIUM CONSTANT (Kc)

Equilibrium constant is the ratio of the concentration of products to the concentrations of reactants at equilibrium.

aA(g)+bB(g) ⇋ cC(g)+dD(g)

The equilibrium expression:

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

You must keep in mind the following:

Kc value has no units because it is a ratio of concentrations.

a,b,c,d represent coefficients of the reactants and products, and are put as exponents in the Kc expression.

Always use square brackets [ ] to represent concentrations of the substances. Do not use other brackets in the Kc expression but only [ ]

When substituting in the Kc expression formula, use only round brackets ( ) not square brackets [ ].

Note:	Reason:
Do not include solid and pure liquid substances in the Kc expression.	Concentration of solids and pure liquids remains constant throughout the reaction.

Always remember the following:

1. Kc = 1

Concentrations of the reactants are equal to the concentration of the products.

2. Kc > 1

Higher concentration of the products formed than reactants.

This implies that equilibrium position shifts to the right.

Forward Reaction is favoured.

High yield/more product is formed

3. Kc < 1

Higher concentration of the reactants formed than products.

This implies that equilibrium position shifts to the left.

Reverse reaction is favoured.

Low yield/ less product is formed

4.4.1 Factors affecting equilibrium constant (Kc).

Temperature is the only factor that changes the value of Kc.

Kc is temperature dependent.

Note: You must know that the following factors do not affect equilibrium constant at all.

- Concentration
- Pressure
- Catalyst

Worked Example 5

Write the Kc expression of the following equations chemical equations.

5. 1 H_2 (g) + Cl_2(g) ⇌ 2HCl (g) (1)

5.2 N_2(g) + 3 H_2(g) ⇌ 2 NH_3(g) (1)

5.3 2A(s) + B(l) ⇌ 2C(s) + D(aq) (1)

Solutions for Worked Example

5.1 Hint: Check if the chemical equation is balanced.

Avoid writing expression as $K_c = \frac{[products]}{[reactants]}$ No mark for this expression.

Always remember that concentration of the products are on the numerator and concentration of the reactants are on the denominator.

Ans: $K_c = \frac{[HCl]^2}{[H_2][Cl_2]}$ ✓

5.2 $K_c = \frac{[NH_3]^2}{[H_2]^3[N_2]}$ ✓ (1)

5.3 Hint: Remember that solids and pure liquids should not be part of Kc expression since their concentrations are constant throughout the reaction.

Ans: $K_c = [D]$ ✓

IMPORTANT STEPS TO CALCULATE KC VALUE

1. Draw table and fill it.

	Reactant	**Product**
	Coefficients from balanced equation	Coefficients from balanced equation
R - Mole ratio		
I - Initial quantity(mol)		
C - Change (mol)/ moles used or formed		

E - Moles at equilibrium (mol)		
Equilibrium concentration (mol·dm^{-3}) $c = \frac{n}{V}$		

Change in mole/ mole used or formed is denoted by Δn

2. Calculate change in mole of reactants using the equation below if they are not given.

Δn = n(initial) – n(equilibrium)

Calculate the change in mole of the products using mole ratio.

Ratio of Reactants: Ratio of products using balanced equation.

This is the only value on the table that will make use of stoichiometry with use of the mole ratios.

3. Calculate quantity of moles at equilibrium of the reactants if not given using:

n(equilibrium) = n(initial) + Δn Use this formula for reactants only

Calculate the quantity of mole at equilibrium of the products using :

Quantity (mol) at equilibrium of the product = Δn of the product/number of moles formed of the product.

You can use this formula also if you know the change in moles formed.

n(equilibrium) = n(initial)-Δn Use this formula for products only

4. Calculate the concentration at equilibrium using $c = \frac{n}{V}$

5. Write the Kc expression without including concentration of the solids and pure liquids.

6. Substitute concentration values into the Kc expression.

7. Write Kc value with no units.

Note: Initial quantity of mole/concentration of the products before the reaction starts is equal to zero ONLY if reactants are added to the container initially.

Worked Example 6

In the reaction, 5 moles of $N_2(g)$ and 8 moles of H_2 gas is introduced into a sealed 5 dm^3 container. The reaction reaches equilibrium at 400 K. At equilibrium, it is found that 2 moles of NH_3 (g) is present in the container.

$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g) + heat$

6.1.1 Calculate the Kc value at this temperature. (7)

6.1.2 Is the reaction ENDOTHERMIC OR EXOTHERMIC? (1)

6.1.3 Explain the answer in QUESTION 6.1.2 (1)

6.2 The temperature of the reaction is decreased to 300 K at equilibrium.

6.2.1 State whether the value of Kc will INCREASE or DECREASE. (1)

6.2.2 Use Le Chatelier's principle to explain the answer in QUESTION 6.2.1 (3)

Solution for Worked Example 6

6.1 Hint: Remember to follow all steps given to you.

	N_2	H_2	NH_3
Ratio	1	3	2
Initial quantity(mol)	5	8	0
Change (mol)/ mol used or formed	1 (x)	3 (3x)	2 $\Delta n=n_{eq}-n_i$ =2-0= 2 (2x=2)
Quantity at equilibrium (mol)	5-1 = 4	8-3 = 5	2
Equilibrium concentration (mol·dm^{-3}) $c = \frac{n}{V}$	$\frac{4}{5} = 0.8$	$\frac{5}{5} = 1$	$\frac{2}{5} = 0.4$

$$K_c = \frac{[NH_3]^2}{[H_2]^3[H_2]}$$ ✓

$$Kc = \frac{(0.4)^2}{(0.8)(1)^3}$$ ✓

$$Kc = 0.2$$ ✓

6.1.2 Exothermic reaction (1)

6.1.3 Energy is released by the system. (1)

6.2.1 Hint: Temperature decrease from 400K to 300K (1)

Forward reaction is exothermic

A decrease in temperature favours the exothermic reaction

Equilibrium position will shift to the right

Ans: Increases✓

6.2.2 Decrease in temperature favours exothermic reaction✓ (4)

Forward reaction is exothermic reaction. ✓

Forward reaction is favoured. ✓

Concentration of NH_3 will increase/More product will be formed. ✓

Worked Example 7

Nitrosyl bromide decomposes to form nitrogen(II) oxide and bromine gas according to the balanced equation below:

$2NOBr\ (g) \rightleftarrows 2NO\ (g) + Br_2\ (g)$

55 g NOBr is sealed in a 2 dm^3 container and allowed to decompose. At equilibrium, 78% of the NOBr has decomposed.

7.1 Calculate the Kc value for this reaction. (8)

7.2 The same reaction takes place at the same temperature, but in a 1 dm^3 container. How will the following be influenced?

(Write only INCREASE, DECREASE or STAY THE SAME.)

7.2.1 Kc value. (2)

7.2.3 Time, it takes to reach equilibrium (2)

7.2.4 The number of moles of Br_2 (2)

7.2.5 Use Le Chatelier's principle to fully explain your answer in 7.2.4. (3)

Solution for Worked Example 7

7.2.1 1. Remember to write down the data first.

m(NOBr) = 55 g

V = 2 dm^3

Note:

Initial quantity of moles is not given but mass is given.

So, use mass to calculate initial number of moles but calculate first the molar mass of NOBr.

M(NOBr) = 14 +16+80 = 110 $g.mol^{-1}$

Then you can calculate initial quantity of moles of NOBr

$$n= \frac{m}{M}$$

$$n= \frac{55}{110}$$

n=0.5 mol (Initial quantity of moles of NOBr)

NB: 78% of NOBr decomposes means 78% of NOBr is used to form product.

Number of moles reacted or used = 78% of n(NOBr)

$$= \frac{78}{100} \times 0.5 = 0.39 \text{ mol reacted/used}$$

Remember to divide by 100% when converting percentage to decimal

Draw table and fill it using given data and use steps given to calculate Kc.

Know these steps by heart.

Get these coefficient's from the balanced equation

Calculate this value by getting 78% of 0.5. 0.78 x 0.5 = 0.39

	NOBr(g)	NO(g)		Br_2(g)
Ratio	2	2		1
Initial quantity(mol)	0.5	0		0
Change (mol)/ mol used or formed	0.39	0.39		0.195
Quantity at equilibrium (mol)	0.5-0.39 = 0.11	0.39 0.39		0.195
Equilibrium concentration (mol·dm^{-3}) $c = \frac{n}{V}$	$\frac{0.11}{2}$ $= 0.055$	$\frac{0.39}{= 2}$ $= 0.195$		$\frac{0.195}{2}$ $= 0.0975$

Always use mole ratios to calculate Δn

Divide by volume

Write Kc expression

Hint: Do not forget to write coefficients of the substances as exponents/powers

Kc= $\frac{[NO]^2[Br_2]}{[NOBr]^2}$✓

Kc= $\frac{(0.195)^2 \quad (0.0975)}{(0.055)^2}$✓

Kc=1.23✓

7.2.2 Hint: Remember that Kc is only affect by change in temperature

Temperature did not change, which implies no change in Kc value

Ans: STAYS THE SAME

7.2.3 Hint: Note that volume is decreased from 2 dm^3 to 1 dm^3

Remember that concentration is inversely proportional to volume.

Decrease in volume will increase the concentration.

Remember also that increase the concentration, increases the rate of reaction.

Ans: INCREASES

7.2.4 Hint: Relate volume to pressure.

Remember that a decrease in volume, increases pressure.

Side with less number of gaseous moles will be favoured.

Reverse reaction has smaller gas moles of reactant

Reverse reaction will be favoured, means less product formed

Ans: DECREASES

7.2.5 When the volume is decreased, the pressure increases. ✓

According to Le Chatelier's principle the reaction that leads to the smaller number of molecules/gaseous moles will be favoured. ✓

Reverse reaction is favoured.

Worked Example 8

Initially 608 g pure carbon dioxide, $CO_2(g)$, is reacted with carbon, C(s), in a sealed container of volume 3 dm^3. The reaction reaches equilibrium at temperature T according to the following balanced equation:

$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$

At equilibrium, it is found that the concentration of the carbon dioxide is

0,054 $mol \cdot dm^{-3}$

8.1 Calculate the equilibrium constant, Kc, for this reaction at temperature T (7)

Solution for Worked Example 9

Solution for Worked Example 9

1. Write down the given data

m = 60.8 g CO_2 (initial mass)

V = 3 dm^3

At equilibrium: c = 0.054 $mol.dm^{-3}$ (CO_2)

Let's analyse what is given to us.

We are given total mass of CO_2, so we can use it to calculate initial quantity of moles of CO_2.

First calculate the molar mass of CO_2

M(CO_2) = 12+(16x2) = 44 $g.mol^{-1}$

$$n = \frac{m}{M}$$

$$n = \frac{60.8}{44} = 1.382 \text{ mol } (CO_2)$$

Now we can calculate the initial concentration of CO_2 using initial moles and volume given since we are given concentration at equilibrium not moles.

NOTE: *You can use values of moles or concentration, in this case let us use concentration.*

$$c = \frac{n}{V}$$

$c = \frac{1,382}{3} = 0,461\ mol.dm^{-3}$ (initial concentration of CO_2)

Draw a table and complete it using steps that were given earlier.

	CO_2 (g)	**CO (g)**	
Ratio	1	2	
Initial concentration ($mol \cdot dm^{-3}$)	0,461	0	
Change ($mol \cdot dm^{-3}$)	0,461- 0,054 = 0,407	0,814	Use Ratio
Equilibrium concentration ($mol \cdot dm^{-3}$)	0,054	0,814	

Write Kc expression

Hint: Remember that we do not include concentration of solids in the expression.

$$Kc = \frac{[CO]^2}{[CO_2]}$$

$$Kc = \frac{(0,814)^2}{(0,054)}$$

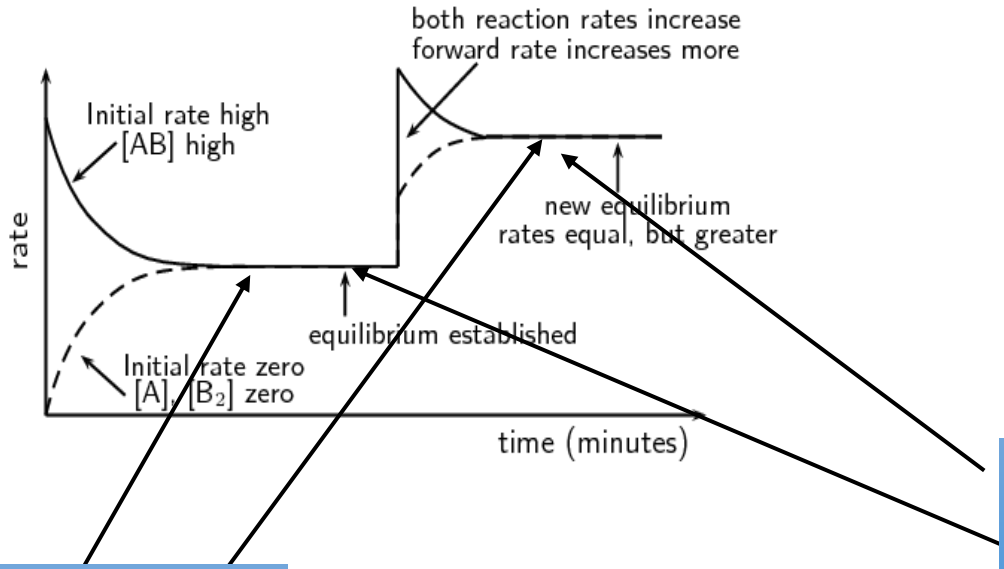
$$Kc = 12,27$$

4.5 INTERPRETATION OF GRAPHS FOR CHEMICAL SYSTEM IN DYNAMIC EQUILIBRIUM

Dynamic equilibrium now can be represented graphically.

We are going to focus only to factors that affect chemical equilibrium.

In this section, we will incorporate the rate of reaction and chemical equilibrium.



Note:

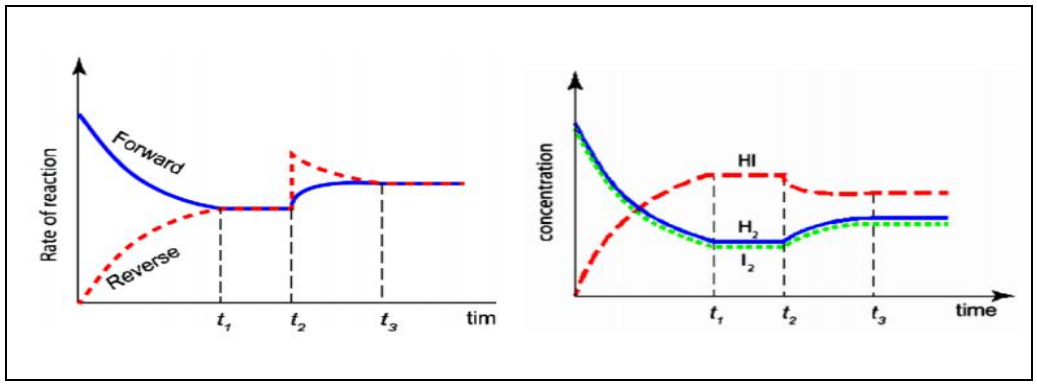
Concentration of reactants and products remains constant at equilibrium

Note:

Rate of forward reaction equals the rate of reverse reaction.

4.5.1 INCREASING TEMPERATURE

H_2 (g) + I_2 (g) ⇌ 2HI(g) $\Delta H < 0$



At t_2 the temperature is increased

Increasing temperature increases both the rate of the forward and the rate of the reverse reaction, but the rate of **endothermic reaction will be more favoured,** since the system aims at decreasing the temperature.

According to Le Chatelier's principle

Increase in temperature favours endothermic reaction.

Reverse reaction is endothermic.

Reverse reaction is favoured.

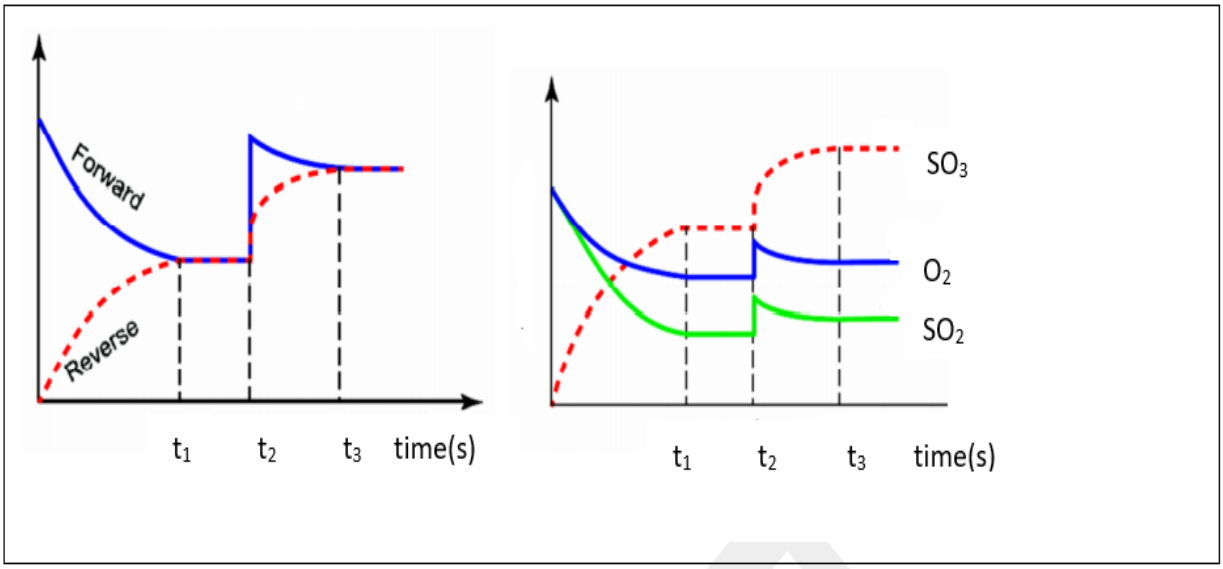
Concentration of H_2(g) and I_2(g) increases.

Concentration of HI(g) decreases.

4.5.2 CHANGING THE PRESSURE

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

> Note:
>
> If pressure is in increased all concentration increased initially



At t_2 pressure is increased.

Increase in the pressure will increase both the rate of forward reaction and the rate of reverse reaction but the reactions that leads to few amount of gas moles will be favoured.

According to Le Chatelier's principle

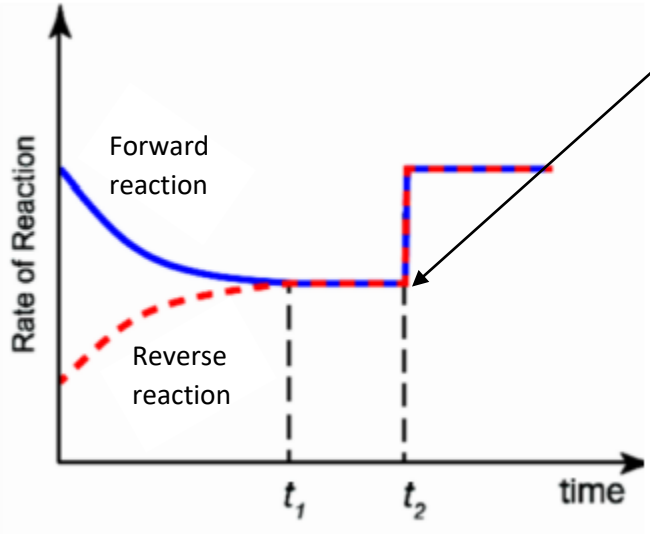
Increase in pressure by decreasing a volume, the reaction leading to the smaller amount of gaseous moles will be favoured.

Forward reaction leads to smaller amount of gaseous moles.

Forward reaction will be favoured.

Concentration of $SO_3(g)$ will be increased.

4.5.3 ADDITION OF A CATALYST AT EQUILIBRIUM



Important.

Both the rate of the forward reaction and reverse reaction increase equally.

Note:

Remember that a catalyst does not affect the chemical equilibrium position.

At t_2, there is addition of a catalyst at equilibrium.

Adding a catalyst will increase both the rate of the forward reaction and the rate of reverse reaction equally.

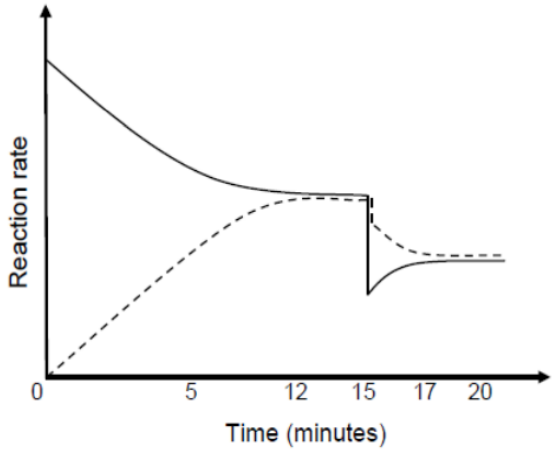
Position of equilibrium will not be affected.

Worked Example 9

Pure hydrogen iodide, sealed in a 2 dm^3 container at 721 K, decomposes according to the following balanced equation:

$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $\Delta H = +26\ kJ \cdot mol^{-1}$

The graph below shows how reaction rate changes with time for this reversible reaction.



9.1 Which line represent the forward reaction? Dotted or Bold line. (2)

9.2 How is the rate of forward reaction and the rate of reverse reaction between 17 min and 20 min? (2)

Give a reason for your answer? HIGHER, LOWER, EQUAL TO.

9.3 How does the concentration of the reactant change between the 12th and the 15th minute? Write down only INCREASES, DECREASES or NO CHANGE. (1)

9.4 The rates of both the forward and the reverse reactions suddenly change at t = 15 minutes.

9.4.1 Give a reason for the sudden change in reaction rate. (1)

9.4.2 Fully explain how you arrived at the answer to QUESTION 9.4.1 (3)

Solution for Worked Example 9

9.1 Hint: Rate of the forward reaction at the beginning is higher than the rate of the reverse.

Ans: **Bold lines**

9.2 Note: The reaction has reacted a dynamic equilibrium..

Ans: **Equal to**

9.3 Hint: The reaction reaches state of equilibrium at 12th and the 15th minute.

Remember that concentration of the reactants and products remains constant at equilibrium.

Ans: NO CHANGE

9.4.1/ 9.4.2 Hint: Identify what happens when there is a change in the rate/ concentration of each substance.

You must note that change in the pressure cannot affect the chemical equilibrium position because number of gas moles is equal in both reaction.

Forward reaction is endothermic

Reverse reaction is exothermic

Ans: There is a decrease in temperature.

4.6 Multiple Choice Questions

Question 1

Multiple Choice Questions

1.1 Which ONE of the following will have no effect on the equilibrium position of any chemical reaction? (2)

A Addition of a catalyst

B Removal of a product

C Change in temperature

D Change in concentration

1.2 A certain chemical reaction reaches equilibrium at 25 °C. The equilibrium constant, Kc, for the reaction at this temperature is $1,0 \times 10^{-4}$. (2)

Which ONE of the following statements regarding this reaction at equilibrium is CORRECT?

A The concentration of the products is equal to that of the reactants

B The concentration of the products is higher than that of the reactants

C The concentration of the products is lower than that of the reactants

D The rate of the forward reaction is lower than the rate of the reverse reaction.

1.3 The reaction represented below reaches equilibrium in a closed container. (2)

$CuO(s) + H_2(g) \rightleftharpoons Cu(s) + H_2O(g)$ $\Delta H < 0$

Which ONE of the following changes will increase the yield of products?

A Increase temperature

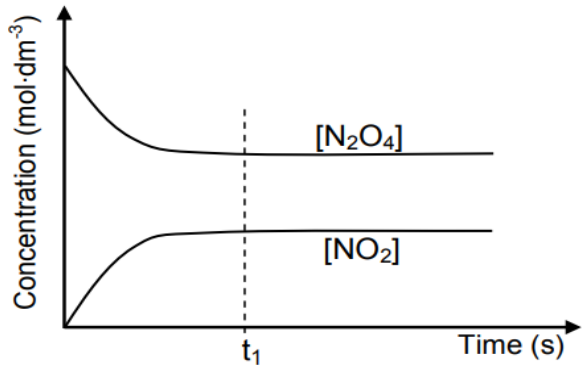
B Decrease temperature

C Increase pressure by decreasing the volume

D Decrease pressure by increasing the volume.

1.4 The graph below represents the decomposition of $N_2O_4(g)$ in a closed container according to the following equation: (2)

$N_2O_4(g) \rightleftharpoons 2NO_2(g)$



Which ONE of the following correctly describes the situation at t_1?

A The N_2O_4 gas is used up.

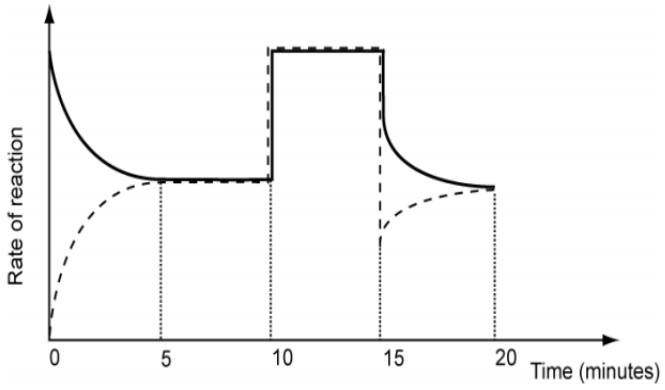
B The NO_2 gas is used up.

C The rate of the forward reaction equals the rate of the reverse reaction

D The concentrations of the reactant and the product are equal.

1.5 The following reversible reaction reaches equilibrium in a closed container: (2)

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $\Delta H < 0$ Equilibrium was first established after 5 minutes. (The broken line on the graph represents the reverse reaction.)



What possible change could have been made to the reaction conditions at t = 10 minutes?

A The temperature was increased

B catalyst was added

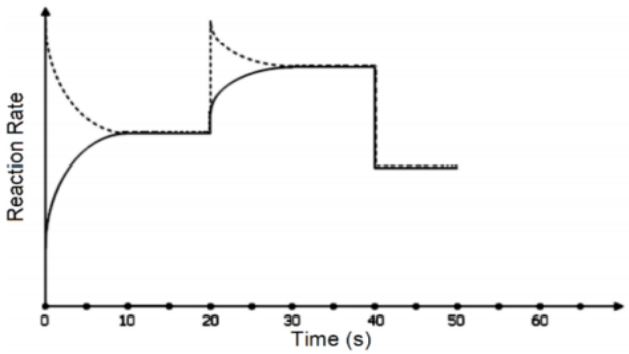
C The temperature was decreased

D The external pressure on the reaction mixture was decreased. (2)

1.6 A mixture of SO_2 gas and O_2 gas was placed into a closed container at 300°C with a small amount of V_2O_5 .

$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$

At certain times, various changes in the physical conditions applicable to the reaction or to the chemicals themselves, were made. The graph below represents the rate of reaction against time.



Which one of the changes below explains the change in the graph at 20 s?

A Increase in pressure.

B Decrease in pressure.

C Decrease in temperature.

D Addition of a catalyst.

1.7 Which statement is CORRECT for a system in DYNAMIC EQUILIBRIUM? (2)

A All reactants are used up

B The forward reaction is equal to the reverse reaction

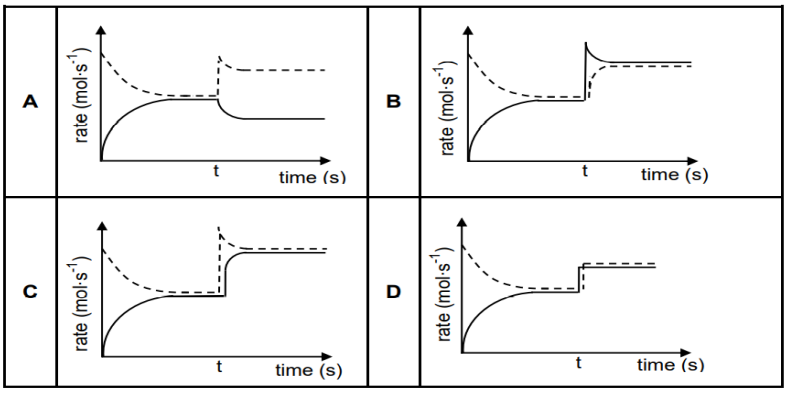
C All substances in the reaction are of equal concentration.

D The concentration of the reactants and products remain constant.

1.8 Initially, a certain amount of P(g) was placed in an empty container. The hypothetical reaction reaches equilibrium in a closed container according to the following balanced equation: (2)

$P(g) \rightleftharpoons 2Q(g) \quad \Delta H < 0$

At time t, the temperature is increased. Which graph below best illustrates the resulting changes in the rates of the forward and reverse reactions after the temperature is increased?



1.9 Study the following reaction at equilibrium at a certain temperature. (2)

$2SO_3(g) \rightleftharpoons O_2(g) + 2SO_2(g)$ H > 0

Which ONE of the following factors will change the Kc value?

A Adding more $SO_2(g)$.

B Adding a catalyst.

C Increasing the temperature

D Increasing the pressure by decreasing the volume

1.10 Consider the following statements about the chemical equilibrium ...

$4A(s) + CD_2(g) \rightleftharpoons 2A_2D(s) + C(s)$ ($\Delta H < 0$)

I the reverse reaction is endothermic.

II the equilibrium constant depends on the concentration of CD_2

III the concentration of C increases when the temperature is decreased.

IV adding more A(s) will increase the amount of C(s) at equilibrium.

Which statements are CORRECT?

A I and II

B II and III

C II and IV

D III and IV

(2)

[10]

4.7. Structured Questions

Question 2

Initially 60,8 g pure carbon dioxide, $CO_2(g)$, is reacted with carbon, C(s), in a sealed container of volume 3 dm^3. The reaction reaches equilibrium at temperature T according to the following balanced equation:

$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$

2.1 Define the term chemical equilibrium. (2)

2.2 At equilibrium, it is found that the concentration of the carbon dioxide is 0,054 $mol \cdot dm^{-3}$.

Calculate the:

2.2.1 Equilibrium constant, K_C, for this reaction at temperature T (7)

2.2.2 Minimum mass of C(s) that must be present in the container to obtain this equilibrium (3)

2.3 How will EACH of the following changes affect the AMOUNT of CO(g) at equilibrium? Choose from INCREASES, DECREASES or REMAINS THE SAME.

2.3.1 More carbon is added to the container (1)

2.3.2 The pressure is increased by reducing the volume of the container at constant temperature. Use Le Chatelier's principle to explain the answer. (3)

2.4 The table below shows the percentages of $CO_2(g)$ and CO(g) in the container at different temperatures.

TEMPRERATURE (°C)	$CO_2(g)$	CO (g)
827	6,23	93,77
950	1,32	98,68
1050	0,37	99,63
1200	0,06	99,94

Is the reaction **EXOTHERMIC** or **ENDOTHERMIC**? Refer to the data in the table and explain the answer. (3)

[19]

Question 3

A chemical engineer studies the reaction of nitrogen and oxygen in a laboratory. The reaction reaches equilibrium in a closed container at a certain temperature, T, according to the following balanced equation:

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

Initially, 2 mol of nitrogen and 2 mol of oxygen are mixed in a 5 dm^3 sealed container. The equilibrium constant (K_C) for the reaction at this temperature is $1,2 \times 10^{-4}$.

3.1	Is the yield of NO(g) at temperature T, HIGH or LOW? Give a reason for the answer.	(2)
3.2	Calculate the equilibrium concentration of NO(g) at this temperature.	(8)
3.3	How will each of the following changes affect the YIELD of NO(g)? Write down only **INCREASES, DECREASES** or **REMAINS THE SAME**.	
3.3.1	The volume of the reaction vessel is decreased at constant temperature.	(1)
3.3.2	An inert gas such as argon is added to the mixture.	(1)
3.4	It is found that Kc of the reaction increases with an increase in temperature. Is this reaction exothermic or endothermic? Explain the answer.	(3)

[15]

Question 4

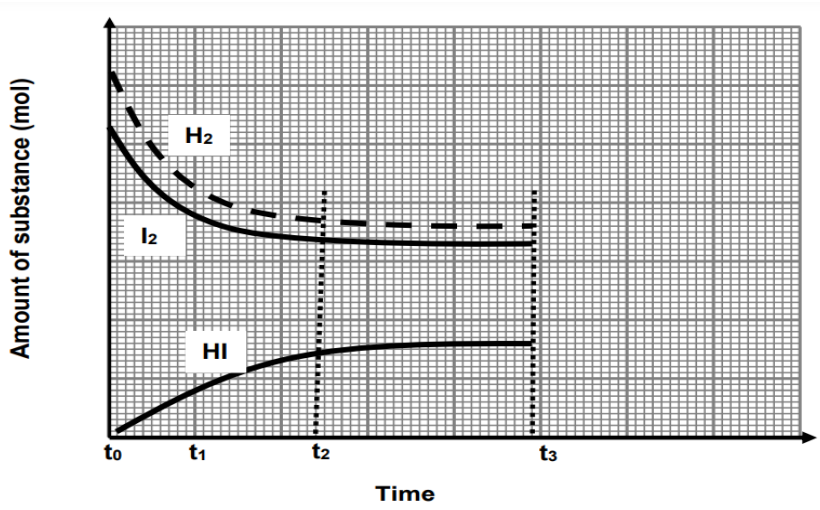
Consider the reversible reaction taking place in a closed container:

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$

4.1 Define the term reversible reaction. (2)

The graph below shows the changes in the amount of the substances H_2, I_2 and HI from the moment the reactants are pumped into an empty container.

GRAPH OF AMOUNT OF SUBSTANCE VERSUS TIME



4.2 Which reaction (FORWARD or REVERSE) has a HIGHER rate of reaction during the interval t_0 to t_1? (1)

4.3 Did the chemical reaction stop during the interval t_2 to t_3? Write only **YES** or **NO**. (3)

Give a reason for the answer.

4.4 At time t_3 the pressure on the equilibrium system is increased by decreasing the volume at constant temperature.

How will the increase in pressure affect the following? Write down only **INCREASES, DECREASES** or **REMAINS THE SAME.**

4.4.1 Rate of reaction (1)

4.4.2 Number of moles of HI. (1)

4.4.3 Concentration of HI. (1)

4.4.4 Explain the answer to QUESTION 4.4.3 above. (2)

4.5 The table below shows the equilibrium constants, Kc values for the reaction at different temperatures.

TEMPERATURE (°C)	Kc
448	50.3
227	129

4.5.1 Is there a HIGH or LOW YIELD at 227 °C? (3)

Give a reason for the answer.

4.5.2 Is the forward reaction **EXOTHERMIC** or **ENDOTHERMIC**? (4)

Explain the answer by referring to Le Chatelier's principle

4.6 The reaction is started by placing hydrogen gas (H_2) and iodine gas (I_2) into an empty 0,5 dm^3 container which is then sealed and heated.

When the reaction reaches equilibrium at 448 °C it is found that the concentration of H_2 and I_2 are 0,46 $mol.dm^{-3}$ and 0,39 $mol.dm^{-3}$ respectively.

The value of the equilibrium constant, Kc is equal to 50,3 at 448 °C.

Calculate the:

4.6.1 Concentration of HI at equilibrium (4)

[22]

Question 5

Ten (10) grams of hydrogen gas and 355 g of chlorine gas are heated together in a sealed 500 cm^3 container. Equilibrium is reached at 450 °C.

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$; $\Delta H < 0$

The equilibrium constant for this reaction at 450 °C is 60.

5.1 Calculate the mass of chlorine gas present at equilibrium. (10)

5.2 The temperature is now increased to 550 °C while the volume is kept constant. The system reaches a **NEW** equilibrium.

5.2.1 State Le Chatelier's principle. (2)

5.3 How will the following be affected in this new equilibrium? Write down only **INCREASE, DECREASE** or **REMAINS THE SAME**.

5.3.1 The equilibrium constant. (1)

5.3.2 The volume of H_2 present. (1)

5.4 Use Le Chatelier's principle to explain the answer to QUESTION **5.3.2**. (2)

[16]

Question 6

The table below shows the effect of temperature changes on the value of the equilibrium constant (Kc) when the following reaction takes place in a sealed gas jar:

N_2O_4 (g) ⇌ $2NO_2$ (g)

(colourless gas) (brown gas)

TEMPERATURE (K)	EQUILIBRIUM CONSTANT (Kc)
300	1.00×10^{-1}
400	3.00×10^{1}
500	1.00×10^{3}
600	1.00×10^{4}
700	1.20×10^{4}

6.1 State Le Chatelier's principle. (2)

6.2 What will be the appearance of the gas jar at 700K? (1)

(Choose from COLOURLESS or BROWN)

6.3 Is the reaction EXOTHERMIC or ENDOTHERMIC? Explain using Le Chatelier's Principle (4)

6.4 Write down two ways, other than temperature change, that can increase the RATE of the forward reaction at 500 K. (2)

6.5 State the effect of adding more N_2O_4(g) on the value of the equilibrium constant, Kc. (3)
(Choose from INCREASES, DECREASES or REMAINS THE SAME). Give a reason for your answer.

[12]

Question 7

Carbonyl bromide, $COBr_2$, decomposes into carbon monoxide and bromine according to the following balanced equation:

$COBr_2(g) \rightleftharpoons CO(g) + Br_2(g)$ $\Delta H > 0$

Initially $COBr_2(g)$ is sealed in a 2 dm^3 container and heated to 73 °C. The reaction is allowed to reach equilibrium at this temperature. The equilibrium constant for the reaction at this temperature is 0,19.

7.1 Define chemical equilibrium. (2)

7.2 At equilibrium, it is found that 1,12 g CO(g) is present in the container.

Calculate the:

7.2.1 Equilibrium concentration of the $COBr_2(g)$ (7)

7.2.2 Percentage of $COBr_2(g)$ that decomposed at 73 °C (4)

7.3 Which ONE of the following CORRECTLY describes the Kc value when equilibrium is reached at a lower temperature?

Kc < 0.19	Kc > 0.19	Kc =0.19

(1)

7.4 The pressure of the system is now decreased by increasing the volume of the container at 73 °C and the system is allowed to reach equilibrium.

How will the number of moles of $COBr_2(g)$ be affected? Choose from INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

[17]

Question 8

Hydrogen and iodine are sealed in a 2 dm^3 container. The reaction is allowed to reach equilibrium at 700 K according to the following balanced equation:

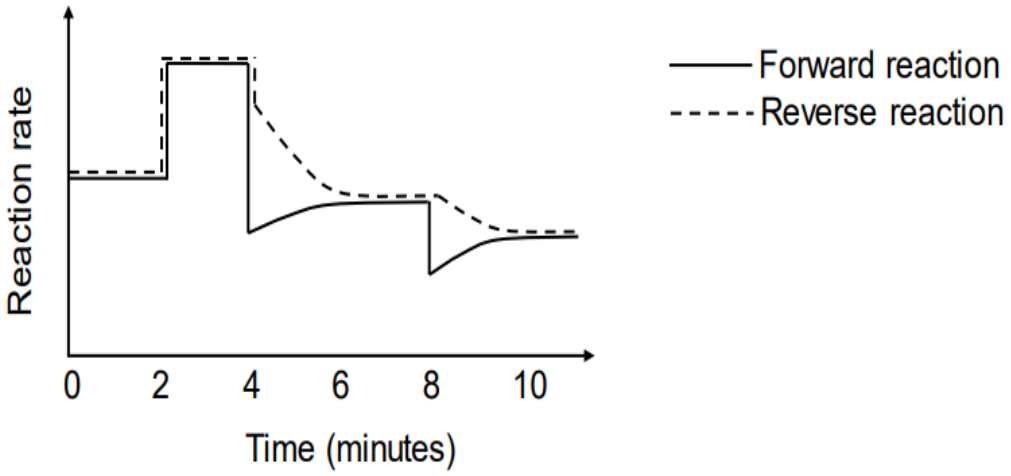
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

8.1 Give a reason why changes in pressure will have no effect on the equilibrium position. (1)

8.2 At equilibrium, 0,028 mol $H_2(g)$ and 0,017 mol $I_2(g)$ are present in the container.

8.2.1 Calculate the initial mass of $I_2(g)$, in grams, that was sealed in the container, if Kc for the reaction is 55,3 at 700 K. (9)

8.3 The reaction rate versus time graph below represents different changes made to the equilibrium mixture.



8.3.1 What do the parallel lines in the first two minutes indicate? (1)

8.3.2 State TWO possible changes that could be made to the reaction conditions at t = 2 minutes. (2)

8.4 The temperature of the equilibrium mixture was changed at t = 4 minutes.

8.4.1 Is the forward reaction EXOTHERMIC or ENDOTHERMIC? (3)
Fully explain the answer.

8.4.2 How will this change influence the Kc value? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

8.5 What change was made to the equilibrium mixture at t = 8 minutes? (1)

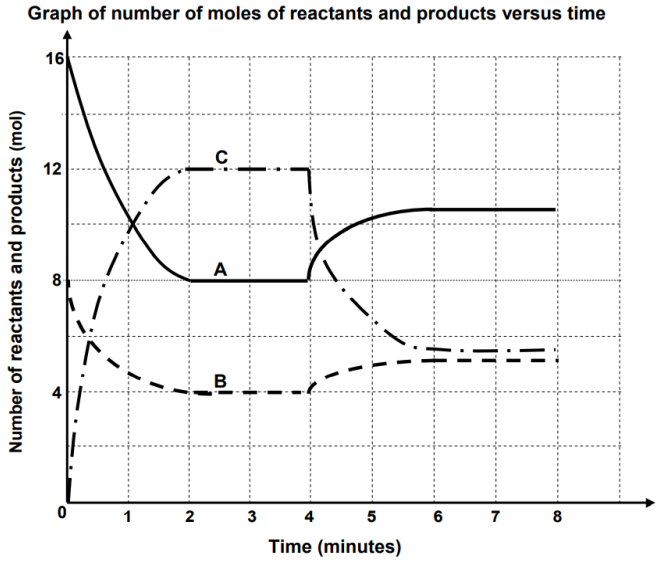
[18]

QUESTION 9

The equation below represents a hypothetical reaction that reaches equilibrium in a closed container after 2 minutes at room temperature. The letters x, y and z represent the number of moles in the balanced equation.

$$xA(aq) + yB(aq) \rightleftharpoons zC(aq)$$

The graph below shows the change in the number of moles of reactants and products versus time during the reaction.



9.1 Define a dynamic equilibrium. (2)

9.2 Use the information in the graph and write down the value of:

9.2.1 X (1)

9.2.2 Y (1)

9.2.3 Z (1)

9.3 Calculate the equilibrium constant, Kc, for this hypothetical reaction at room temperature if the volume of the closed container is 3 dm^3. (7)

9.4 At t = 4 minutes, the temperature of the system was increased to 60 °C. Is the REVERSE reaction EXOTHERMIC or ENDOTHERMIC? Explain how you arrived at the answer. (3)

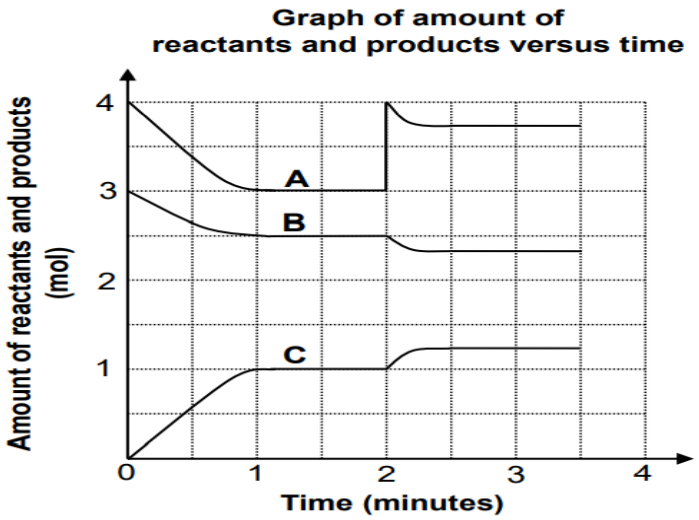
[15]

Question 10

The equation below represents a hypothetical reaction that takes place in a closed container at 350 °C. The letters x, y and z represent the number of moles in the balanced equation.

$xA(g) + yB(g) \rightleftharpoons zC(g)$ $\Delta H < 0$

The graph below shows the change in the number of moles of reactants and products versus time during the reaction.



10.1 Define a reversible reaction. (2)

10.2 After how many minutes did the system reach equilibrium for the first time? (1)

10.3 Use the information in the graph and write down the value of:

10.3.1 X (1)

10.3.2 Y (1)

10.3.3 Z (1)

10.3.4 Calculate the equilibrium constant, Kc, for this reaction at 350 °C if the volume of the container is 4 dm^3 (7)

10.3.5 State the change made to the system at t = 2 minutes and explain the effect of this change with the aid of Le Chatelier's principle. (3)

[16]

4.8 Solutions

QUESTION 1

Remember: Catalyst does not affect equilibrium but only speed up the rate of reaction

1.1 A✓✓

Hint: Kc<1

Implies that concentration of reactants higher than concentration of products

1.2 C ✓✓

1.3 B✓✓ ***Forward reaction is exothermic, decrease in temperature will favour the exothermic reaction.***

1.4 C✓✓ ***The system has reached equilibrium. Concentrations of products and reactants are constant. The rate of the reverse reaction is equal to the rate of the reverse reaction.***

1.5 B✓✓ ***The rate of both the forward and reverse reaction increases.***

1.6 A✓✓ ***Decrease in pressure will favour the reverse reaction.***

1.7 D✓✓

1.8 B✓✓

1.9 C✓✓ ***Only a change in temperature will change the Kc value.***

1.10 A ✓✓ ***Concentration of solids will remain constant throughout the reaction.***

Question 2

2.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction.✓ ✓

2.2.1 $n(CO_2) = \frac{m}{M}$

$= \frac{60,8}{44}$✓

= 1,382 mol

	CO_2	CO
	1	2
Initial quantity (mol)	1,382	0
Change (mol)	1,22✓	2,44✓
Quantity at equilibrium (mol)	0,162	2,44
Equilibrium concentration ($mol.dm^{-3}$)	0,054	0,813✓

$K_c = \frac{[CO]^2}{[CO_2]}$✓

$= \frac{(0,813)^2}{(0,054)}$✓

= 12,24✓

2.2.2 n(C)reacted = n(CO2)reacted = 1,22 mol✓

m(C) = nM = 1,22(12) ✓ = 14,64 g✓

2.3.1 Remains the same✓

2.3.2 Decreases✓

• (When pressure is increased) the reaction that leads to the smaller amount/number of moles/volume of gas is favoured. ✓

• The reverse reaction is favoured. / More CO_2 is formed. ✓

Question 3

3.1 Low. ✓ Kc is smaller than 1✓

3.2

	N_2	O_2	NO
Initial quantity (mol)	2	2	0
Change (mol)	x✓	x	2x✓
Quantity at equilibrium (mol)	2-x	2-x	2x✓
Equilibrium concentration ($mol.dm^{-3}$)	$\frac{2-x}{5}$	$\frac{2-x}{5}$	$\frac{2x}{5}$✓

$K_c = \frac{[NO]^2}{[N_2][O_2]}$✓

$1,2 \times 10^{-4} = \frac{(\frac{2x}{5})^2}{(\frac{2-x}{5})(\frac{2-x}{5})}$✓

x = 0.0109 mol

$[NO] = \frac{2(0,0109)}{5}$

$= 4,36 \times 10^{-3}$ $mol.dm^{-3}$✓

3.3.1 Remains the same✓

3.3.2 Remains the same✓

3.4 Endothermic

K_c increases, therefore forward reaction was favoured

Temperature increase will favour endothermic reaction

Therefore forward reaction is endothermic

Question 4

4.1 Reaction in which products can be converted back to reactants✓✓

4.2 FORWARD REACTION✓

4.3 No. ✓The rate of forward reaction is equal to the rate of reverse reaction✓

4.4.1 Increases✓

4.4.2 Remains the same✓

4.4.3 Increases✓

4.4 The amount of HI remains constant. ✓The volume decreases. The concentration increases according to $c = \frac{n}{V}$✓

4.5.1 High yield. Kc >1

4.5.2 EXOTHERMIC✓. The value Kc decreases with an increase in temperature. ✓

As temperature increases, the [prdoducts] decreases ✓

Reverse reaction is favoured by an increase in temperature✓

4.6 $K_c = \frac{[HI]^2}{[H_2][I_2]}$✓

$50{,}3$✓$= \frac{[HI]^2}{(0{,}46)(0{,}39)}$

[HI] = 3 mol.dm^{-3}✓

Question 5

	H_2	Cl_2	HCl
	1	1	2
Initial quantity (mol)			
Change (mol)	x✓	x	2x✓
Quantity at equilibrium (mol)	5-x	5-x	5-x✓
Equilibrium concentration (mol.dm^{-3})	$\frac{5-x}{0.5}$	$\frac{5-x}{0.5}$	$\frac{2x}{0.5}$✓

$K_c = \frac{(HCl)^2}{[H_2][Cl_2]}$

$60 = \frac{(2x)^2}{\left(\frac{5-x}{0,5}\right)\left(\frac{5-x}{0,5}\right)}$

$x = 4.23\ mol$

At equilibrium

n(Cl_2) = 5-x

= 5-4,23

= 0,77 mol

$m(Cl_2) = nM\ m(Cl_2) = 0{,}77 \times 71$

$m(Cl_2) = 54{,}67g$

5.2.1 When the equilibrium in a closed system is disturbed, the system will reinstate a new equilibrium by favouring the reaction that will oppose the disturbance. ✓✓

5.3.1 Decrease ✓

5.3.2 Increases

5.4 According to Le Chatelier, and increase in temperature will favour the endothermic reaction, which in this case is the reverse reaction ✓; hence, the concentration of H_2 will increase and thus the volume too.

Question 6

6.1 When the equilibrium in a closed system is disturbed, the system will reinstate a new equilibrium by favouring the reaction that will oppose the disturbance. ✓✓

6.2 Brown✓

6.3 Endothermic. ✓An increase in temperature will favour the endothermic reaction in an equilibrium reaction. ✓

Since an increase in temperature resulted in an increase in the value of Kc, ✓ It can be concluded that the forward reaction is favoured

6.4 Add a catalyst. ✓

Increase the pressure. ✓

Increase concentration of reactant. ✓

6.5 Remains the same. ✓

Only change in temperature affects Kc✓

Question 7

7.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓

7.2.1

	$COBr_2$	CO	Br_2
	1	1	1
Initial quantity (mol)		0	0
Change (mol)	0,04	0,04	0,04
Quantity at equilibrium (mol)	3	0,04	0,04✓
Equilibrium concentration ($mol.dm^{-3}$)		$\frac{0,04}{2} = 0.02$	$\frac{0,04}{2} = 0.02$✓

$K_c = \frac{[CO][Br_2]}{[COBr_2]}$✓

$0,19$ ✓$= \frac{(0,02)(0,02)}{[COBr_2]}$✓

$[COBr_2] = 2,11 \times 10^{-3} mol.dm^{-3}$✓

Question 8

8.1 Amount / number of moles / volume of (gas) reactants equals amount/number of moles/volume of (gas) products

8.2.1 $K_c = \frac{[HI]^2}{[H_2][I_2]}$✓

55,3 ✓$= \frac{[HI]^2}{(0,014)(0,0085)}$ ✓

[HI] = 0,08112 mol.dm^{-3}

$n(HI) = \frac{c}{V}$

$n(HI) = 0,08112 \times 2$

$n(HI) = 0,1662$

	H_2	I	HI
Mole Ratio	1	1	2
Initial quantity (mol)	0,1091	0,09812	0
Change (mol)	0,08112✓	0,08112✓	0,1622✓
Quantity at equilibrium (mol)	0,028	0,017	0,1622
Equilibrium concentration (mol.dm^{-3})	$\frac{0,028}{2} = 0,014$	$\frac{0,017}{2} = 0,0085$	$\frac{0,1622}{2} = 0,0812$

m =nM= 0,09812x254✓ = 24,92 g✓

8.3.1 (Chemical/dynamic) equilibrium✓

8.3.2 Addition of a catalyst. ✓Increase in pressure. ✓

8.4.1 Endothermic ✓

- The rate of the forward reaction decreases more. / The rate of the reverse reaction decreases less. ✓
- A decrease in temperature favours the exothermic reaction✓

8.4.2 Decreases✓

8.5 Reactants / H_2 / I_2 removed✓

QUESTION 9

9.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction✓✓

9.2.1 2

9.2.2 1

9.2.3 3

9.3

	A	B	C
	2	1	3
Initial quantity (mol)	16	8	0
Change (mol)	8	4	12✓
Quantity at equilibrium (mol)	8✓	4✓	12✓
Equilibrium concentration (mol.dm^{-3})	$\frac{8}{3} = 2{,}666$	$\frac{4}{3} = 1{,}3333$✓	$\frac{12}{3} = 4$

$$k_c = \frac{[C]^3}{[A]^2[B]}$$

$$= \frac{4^3}{\left(\frac{8}{3}\right)^2\left(\frac{4}{3}\right)}$$

= 6,75

9.4 Endothermic✓

An increase in temperature favours an endothermic reaction. ✓

An increase in temperature) favours the reverse reaction. ✓

QUESTION 10

10.1 A reaction where products can be converted back to reactants✓

10.2 1 minute

10.3.1 2

10.3.2 1

10.3.3 2

10.3.4

	A	B	C
	2	1	2
Initial quantity (mol)	4	3	0
Change (mol)	1	0,5	1✓
Quantity at equilibrium (mol)	3✓	2,5✓	1✓
Equilibrium concentration (mol.dm^{-3})	$\frac{3}{4} = 0{,}75$	$\frac{2.5}{4} = 0{,}625$✓	$\frac{1}{4} = 0{,}25$

$.K_c = \frac{[C]^2}{[A]^2[B]}$✓

$K_C = \frac{(0.25)^2}{(0.75)^2(0.625)}$✓

$K_c = 0{,}18$✓

10.3.5 Addition of A(g)

According to Le Chatelier's principle, the system will react to decrease/oppose the increase in n(A). ✓

The forward reaction is favoured. ✓

General Examination Tips

As you prepare to write the examination, it is important to carefully understand definitions, principles, chemical equations and concepts very well. You must know how to apply definitions and principles.

Read statement given in the question carefully and underline all key words.

Write down the data given in the statement/diagram or graph

Learn to convert statements to diagrams to simply a scenario.

Write down the information that you do not have.

Use formula sheet to choose suitable formula that you will use.

Do not forget to write SI units if you are dealing with calculations.

Use previous question papers for revision.

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4.10 Reference

The following documents were used in the development of this booklet.

Department of Basic Education Examination Papers.

Eastern Department of Education.

Western Cape Government Education

KZN Department of Education.

Department of Education Free State.

Siyavula Textbook

Learner Support Document grade 10-12. KZN Department of Education.

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